Broadening Effects of the 632.8 nm NeI Line Due to a Helium-Neon Mixture *

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An experimental test of the additivity of perturbation energies produced by collisions of the radiating atom with perturbers is made by measuring the Lorentzian half-width of the 632.8 nm line of NeI under various pressures and with various concentration ratios of a mixture of Ne and He. The Lorentzian half-width produced by the mixture is found to be the sum of half-widths due to each component gas.

In recent years several attempts have been made to develop an unified theory of pressure broadening of spectral lines in order to interpret both the Lorentzian shaped cores, the quasi-static wings and the satellite bands in the intermediate frequency range [1–3]. The fundamental assumption of all these unified treatments is that the perturbation energies caused by numerous collisions of the radiating atom with perturbing atoms during the radiation time are additive. To our knowledge, the only experimental work in which this assumption has been tested in a strict manner is that of Ch'en and Garrett [4]. Their study consisted of the measurement of the pressure shifts of some spectral lines of CsI by employing a mixture of two different perturbing gases, such as He and Ar. The total shift produced by the mixture was found to be the sum of the shifts due to the separate gases, which is a direct evidence of the additivity of interaction energies. The same experiment has shown, however, that the half-width due to a mixture of two gases is smaller than the sum of the half-widths due to each component gas (only 3/4 of the sum). This result can be explained by the fact that at such high pressures as those used by Ch'en and Garrett [4] the line profiles deviate appreciably from Lorentzian.

We have therefore thought it useful to investigate the total broadening produced by a mixture of perturbing gases in the low pressure region, where the lines are described by Lorentzian profiles. In the present paper we report the results of such studies performed for the line 632.82 nm of neon perturbed by He and Ne under various pressures and with various concentration ratios of a mixture of Ne and He. The broadening of this line in the helium-neon mixture (with constant ratio of pressures of component gases) has been the subject of several experimental studies done both under the conditions of laser action in the He-Ne system [5–8] and in the case of spontaneous emission [9]. In these experiments the pressure broadening coefficient $\beta = \Delta\gamma/\Delta p$ has been determined from the slopes of straight lines representing the plots of the Lorentzian half-width γ of the line against the total pressure p of the perturbing gas. It should be emphasized, however, that for the mixture of perturbing gases β defined in this way has its simple physical meaning of the pressure broadening coefficient only under the condition that the interaction energies are additive.

The present investigation has been done for very low pressures (below 25 Torr) using a d.c. glow discharge tube and a photoelectric spectrometer with a Fabry-Perot etalon [10]. The light source as well as the method of analysis of Fabry-Perot interferograms were the same as those in our earlier paper [11]. The measurements of the line profiles were performed for natural neon. However, all line profiles were reduced to the line profiles corresponding to the single neon isotope ^{20}Ne using the method proposed recently [12]. The single isotope line shape (after elimination of the instrumental function) was found to be given by the Voigt profile with the width of the Gaussian component independent of the gas pressure. This result indicates that in our case the velocity changing collisions [13, 14] giving rise to the correlation between Doppler and pressure broadening may be neglected.

Figure 1 shows the plot of the half-width γ of the Lorentzian component of the Voigt profile of the 623.8 nm line of NeI against the pressure of neon (p_{Ne}) for various pressures of helium ($p_{He} = $ const). As can be seen the Lorentzian half-widths γ for different p_{He} depend linearly on the pressure of neon.

Let $\beta_1 = \Delta\gamma/\Delta p_{Ne}$ be the pressure broadening coefficient corresponding to the Ne*-Ne interactions. The values of β_1 determined from the slopes of the straight lines shown in Fig. 1 are

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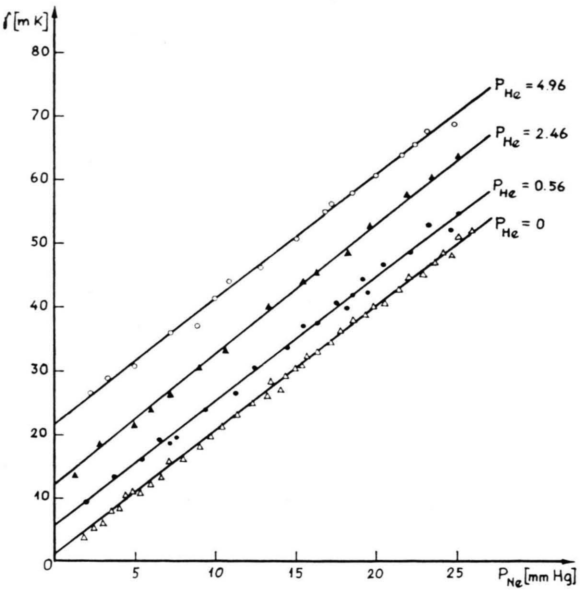

Fig. 1. Dependence of the Lorentzian half-width γ on the neon pressure (p_{Ne}) at various helium pressures (p_{He}).

listed in Table 1. Let us note a good agreement between values of β_1 corresponding to different helium pressures p_{He}.

The values of the coefficient $\beta_2 = \Delta\gamma/\Delta p_{He}$ corresponding to the Ne*-He interactions were determined from the slopes of the straight lines representing the plots of γ against p_{He} for $p_{Ne} =$ const. For $p_{Ne} = 1.83$ Torr β_2 was found to be 12.5×10^{-17} mK/atom cm^{-3}, while the value of β_2

p_{He} [mm Hg]	β_1
0	6.80 (0.1)
0.56	6.66 (0.24)
1.06	6.9 (0.14)
2.46	7.17 (0.3)
4.96	6.76 (0.24)

Table 1. The values of the pressure broadening coefficients β_1 (in units 10^{-17} mK/atom $\times$ cm^{-3}). Numbers in parantheses within the table represent standard deviations of the least-square-fit.

obtained from the plots of γ against p_{Ne} extrapolated to $p_{Ne} = 0$ at $p_{He} =$ const is 12.8×10^{-17} mK/atom cm^{-3}.

As an example let us note that the half-width of this line for pure neon at the pressure 4.96 Torr and temperature 335 K is 9.98 mK and the half-width due to helium at the same pressure and temperature is 20.3 mK (for $p_{Ne} = 1.83$ Torr). On the other hand, for the mixture of Ne and He in equal concentration ($p = 9.92$ Torr) the experimental value of the half-width was found to be 31.12 mK, which is very close to the sum of the two half-widths (30.30 mK).

This significant experimental result indicates that for low pressures and in the case when there is no correlation between the Doppler and collision broadening the total Lorentzian half-width produced by the mixture of Ne and He is the sum of the Lorentzian half-widths due to each component gas. It should be noted that this results are in full agreement with the predictions of all unified line broadening theories [1–3] for the low pressure region. Consequently, our experiment has shown that the theoretical assumption of the additivity of interaction energies is well justified.

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